A Low-Cost High-Specific-Stiffness Mirror Substrate

NNX11CH28P S2.04-8758

Mark Tellam, Director / COO

Introduction

Current Feasibility Study

- ***Material***
- ***Replication***
- ***Coating***
- ***Commercial Characterization***

Future Plan(s)

Summary

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Introduction

Arnold Hill, President / CTO

Florida High Tech Corridor Council (UCF, USF, UFL)

Florida Manufacturing Extension Partnership (FMEP) (NIST_DOC)

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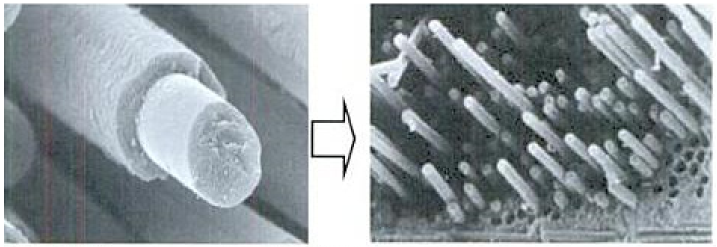


Figure 7.9 Fiber coating and fiber pull-out (EADS).

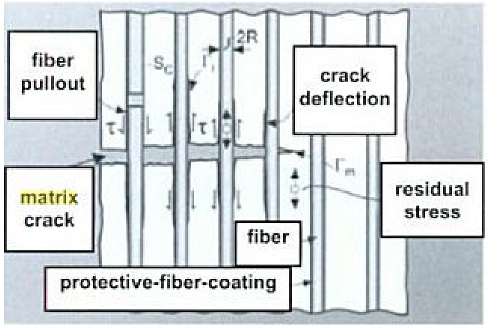
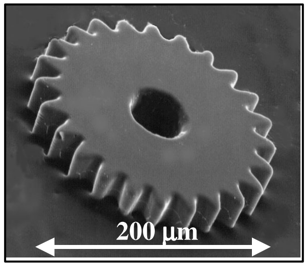


Figure 7.10 Mechanism of "quasi-ductilizing" of a fiber-coated PIP-CMC [37].



Typical Low Dimension PDC Components (refs: ZZZ01, ZZZ02)

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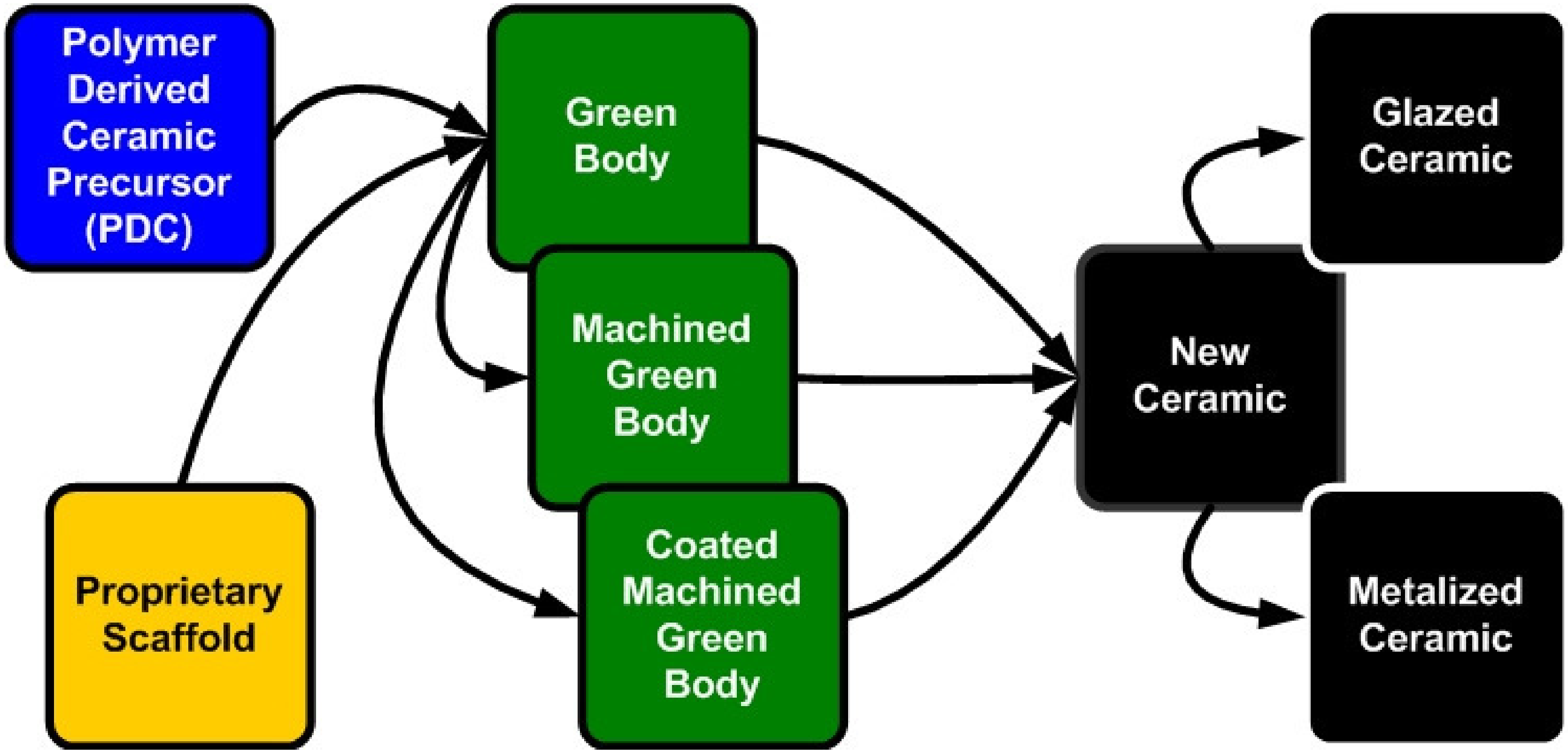

UMS Bulk and Hybrid Material Processes

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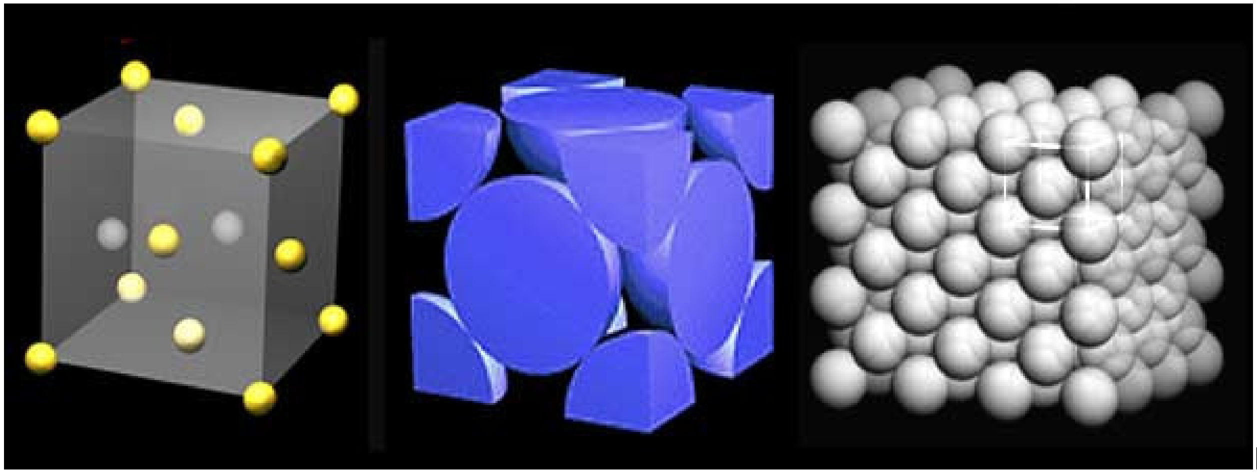
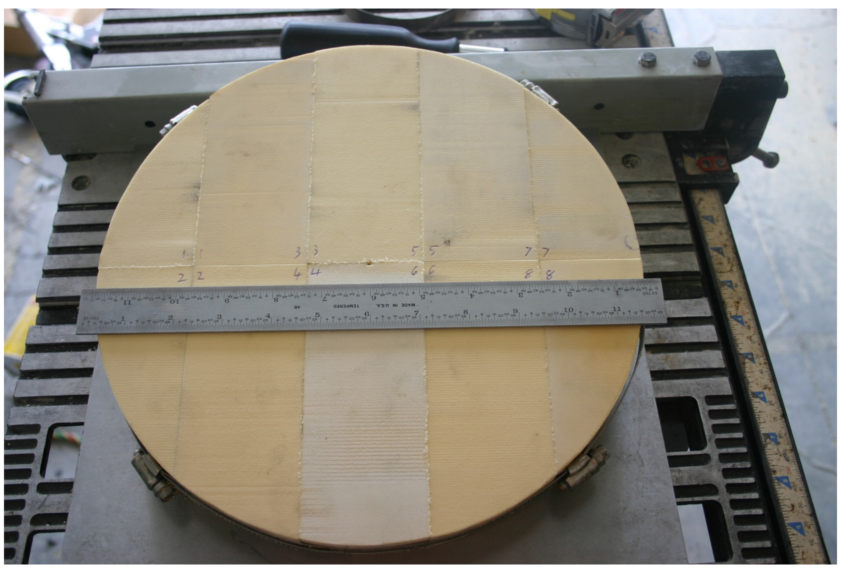
Proprietary Scaffold *(critical design dimension)*



ref: ZZZ03



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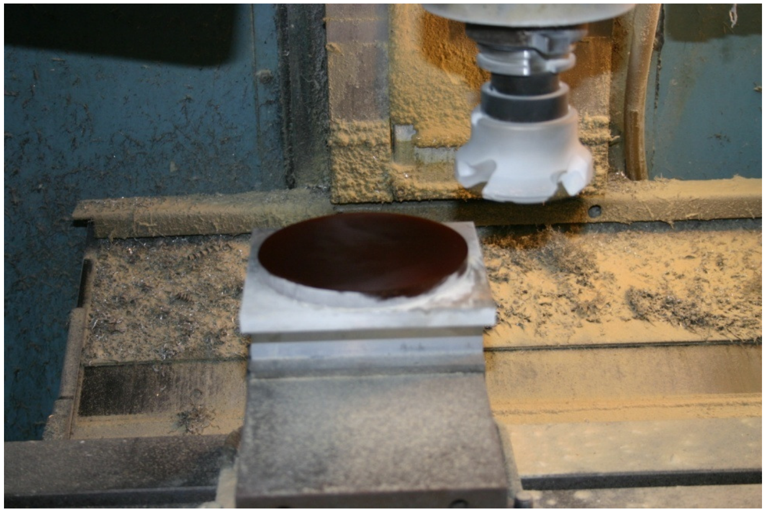

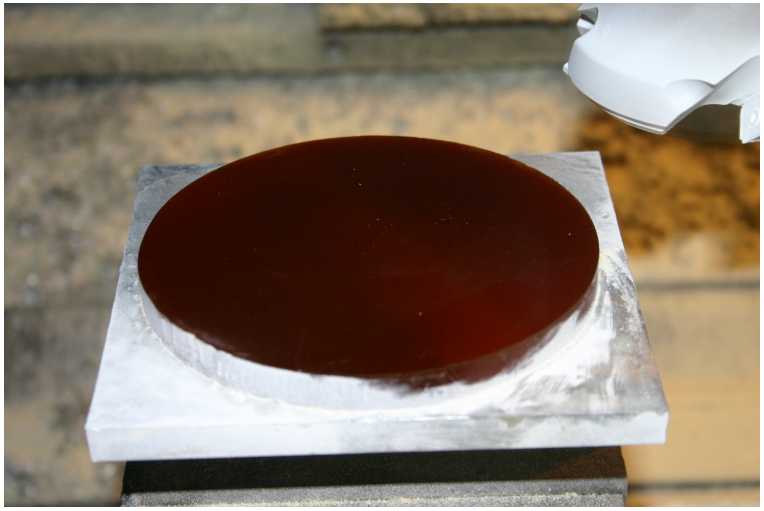

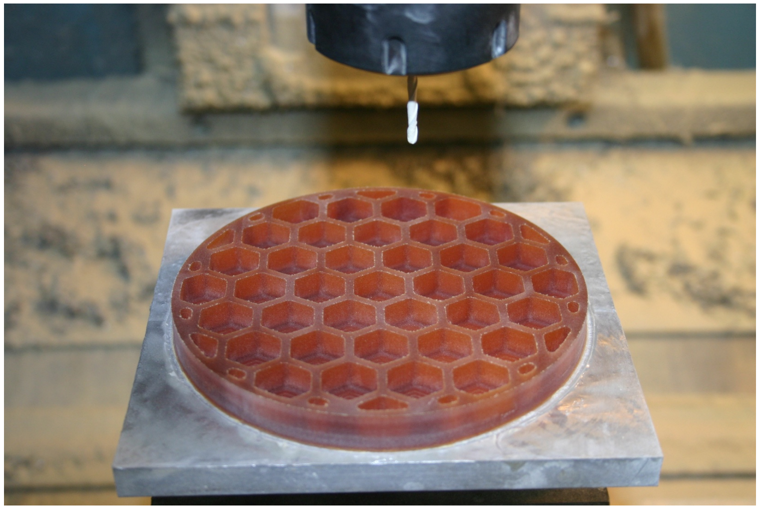

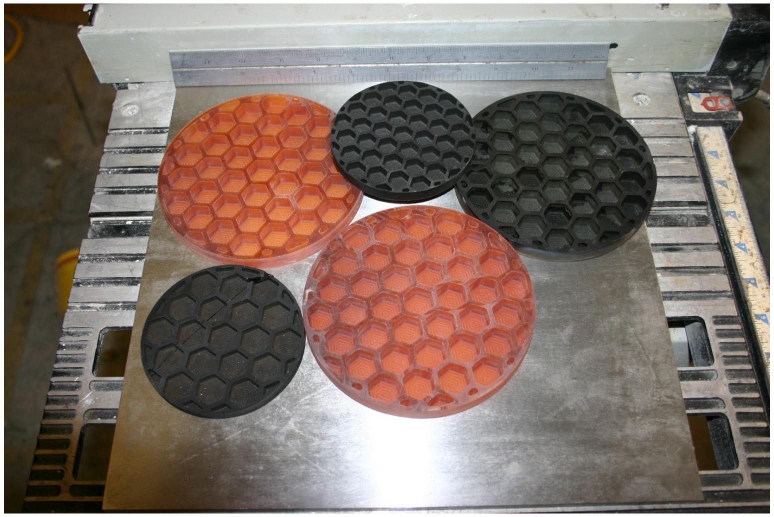

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15cm Mirror Substrate (uncoated)

The End of The Beginning

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Material

Properties of polymer derived SiCN and other ceramics

Properties	SiCN	SiC	Si_3N_4	Alumina	LTCC[@]
Density (g/cm^3)	2.0	3.17	3.19	3.95	3.1
Young's modulus (GPa)	90-150	400	320	400	152
CTE ($x10^{-6}/K$)	1.8	3.8	2.5	8.4	5.8
Thermal conductivity (W/Km)	1.5	40-90	20-40	30-40	3.0
Strength (MPa)	~1000	420	700	400	320
Hardness (GPa)	20	30	28	16	
Thermal Shock *	~3000	350	880	120	360

[@]LTCC, low temperature co-fired ceramics, data based on Dupont 951.*Thermal shock formula = strength/ (E-modulus·CTE), Ceramics data vary because of various sintering methods. refZZZ04

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Your Ceramic From Atoms Up… Ceramicore© *Material*

SiCN *(critical design dimension 10-350 microns)*

Clariant, KiON Defense Technologies

SiOC *(critical design dimension 4000 microns)*

EEMS

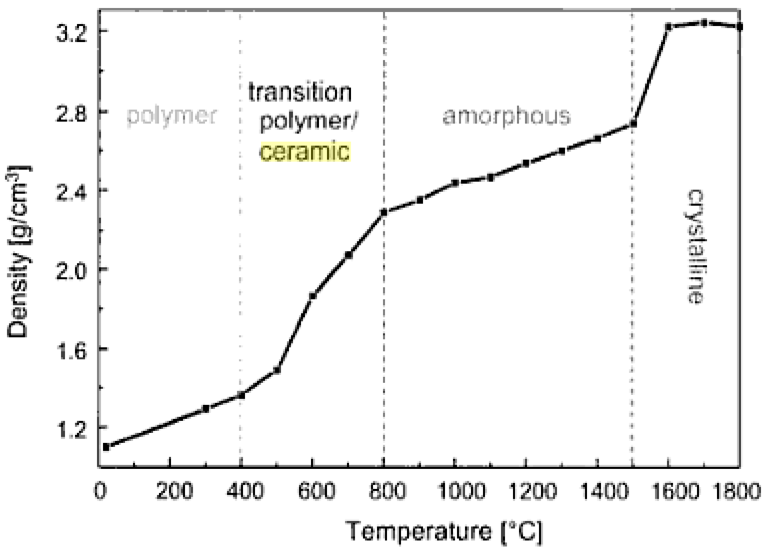
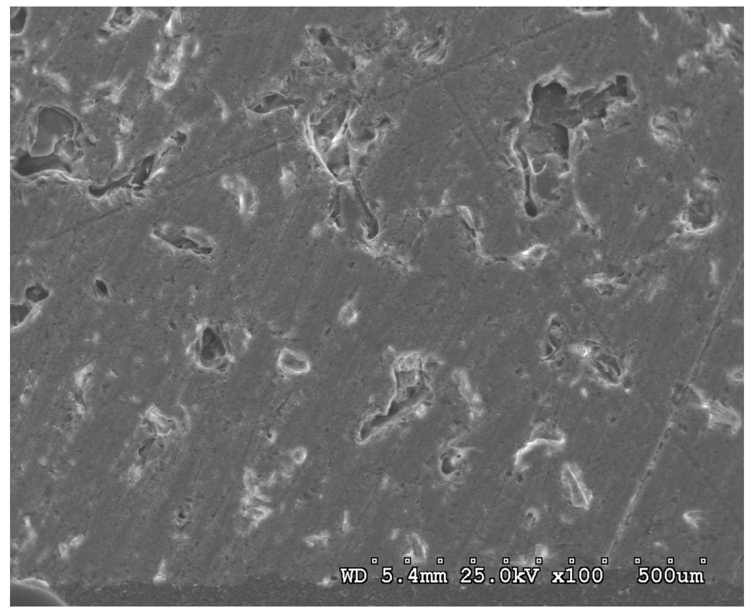


Figure 7.7 Density values of SiCN material after pyrolysis at different temperatures



Reference: ZZZ05

UMS SiCN Greenbody

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Material Characteristics of Targeted PDC Precursors

			Yield % Cross Linked	Pyrolyzed	
KDT	SiCN	HTT1800	98.4	72.9	Polysilazane
KDT	SiCN	PURS20	99.1	75.1	Polysilazane
CLRNT	SiCN	PSZ20	99.9	75.6	Polysilazane
EEMS	SiCN	CZ765_HT	99.8	75.7	Polysilazane
EEMS	SiC	CS160_HT	99	76.5	Allylhydridopolycarbosilane
EEMS	SiOC	CSO310	99.8	76.8	Polycarbosiloxane
EEMS	SiOC	CSO351_HT	97.6	83.6	Polycarbosiloxane
EEMS	SiOC	CSO111_HT	99.2	86.1	Polycarbosiloxane

Material Properties to be Measured

ASTM C20 Standard Test Methods for Apparent Porosity

ASTM E228-06 Standard Test Method for Linear Thermal Expansion of Solid Materials

ASTM C 1161 Rev C Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature

ASTM C 1421 Rev B Standard Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperature

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Scaffold

As Formed Volume (20.237 ; 0.771 mean /stdev cuin)

As Saturated Volume (18.894 ; 0.583 mean /stdev cuin) (delta - 6-7 %)

Green Body (Cross Linked / Polymerized) Volume (delta - 2-3 %)

Pyrolyzed Volume(delta - 20-30 %)

- *Spherocity*
- *Joint Integrity*
- *Local Meso Shape*

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Uncompressed Scaffold

Scaffold is created with a critical dimension that equates to low dimensions in powders and fibers created of PDC. For example; suppose a fiber is formed through a temporal / thermal process yielding a 10 micron diameter strand.

1. *UMS designs a corresponding bulk solid by stacking particles in a hexagonal close pack (HCP) array, where the particles are sized to yield 10 micron ceramic spheres.*
2. *The interstitial space around these HCP arranged particles is filled completely with a sacrificial polymer.*
3. *The contacting HCP arranged particles are removed, leaving the sacrificial polymer scaffold.*
4. *The volume that the removed particles occupied, is filled completely with PDC precursor.*
5. *The PDC precursor is completely cross-linked.*
6. *The material that forms the interstitial network of sacrificial polymer web is removed, leaving the slightly porous cross-linked PDC precursor, which has an isotropic 'HCP like' structure.*

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Uni-axially Compressed Scaffold

In this first stage of the SBIR UMS is compressing scaffold in one axis to determine the effects of cellular distortion on the physical properties of the PMC and the resulting ceramic. Scaffold starts with the proper 'critical' cell size.

- *Two proof of concept fixtures have been built to create uniaxially deformed scaffold*
- *Volume_initial, Volume_final, Density_initial and Density_final are noted.*
- *A 'flat' replicated surface has been produced in the direction of compression.*

Bi-axially Compressed Scaffold

In this first stage of the SBIR UMS is compressing scaffold in two axes to determine the effects of cellular distortion on the physical properties of the PMC and the resulting ceramic. Scaffold starts with the proper 'critical' cell size.

- *Two proof of concept fixtures have been built to bi-axially deform scaffold*
- *Volume_initial, Volume_final, Density_initial and Density_final are noted.*
- *'Flat' replicated surfaces have been produced in both directions of compression.*

Tri-axially Compressed Scaffold

In this first stage of the SBIR UMS is compressing scaffold in three axes to determine the effects of cellular distortion on the physical properties of the PMC and the resulting ceramic. Scaffold starts with the proper ‘critical’ cell size.

- *Two proof of concept fixtures have been built to tri-axially deform scaffold*
- *Volume_initial, Volume_final, Density_initial and Density_final are noted.*
- *‘Flat’ replicated surfaces have been produced in all directions of compression.*

-  

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Compression and Replication

Replicated parts are targeted to have the same initial and final volumes, and to compress scaffold against a 'forming surface' which achieves the desired 'near net' geometry for the reflective surface.

Replicate experiments in this feasibility study aim to

(1) examine boundary conditions at a near net optical face, and

(2) examine boundary conditions of adjoining surfaces of scaffold parts to be combined into a scaffold sub-assembly.

- *The proof of concept fixtures listed above are being used to create scaffold for bricks, and wafers, with at least one 'formed' face'*
- *Volume_initial, Volume_final, Density_initial and Density_final are noted.*
- *The 'formed' face becomes the target for a 'fully dense coating' on the bulk PMC green body substrate*

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Replicates

Replicated Wafers

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Fully Dense Coating Bulk Ceramic

Attention to critical dimensions

Spin Coating

Spin Fully Dense Coating onto Flat Top Green Body (polymerized face is in tension)

Scaffold Forming

Form Green Body onto Fully Dense Film (polymerized face is in compression)

Concurrently Formed Coating

Apply Fully Dense Coating into Recess in Replicate Face concurrent with saturation of Green Body (polymerized face has no differential strain)

Coating typically fractures internally, not at interface with green body.

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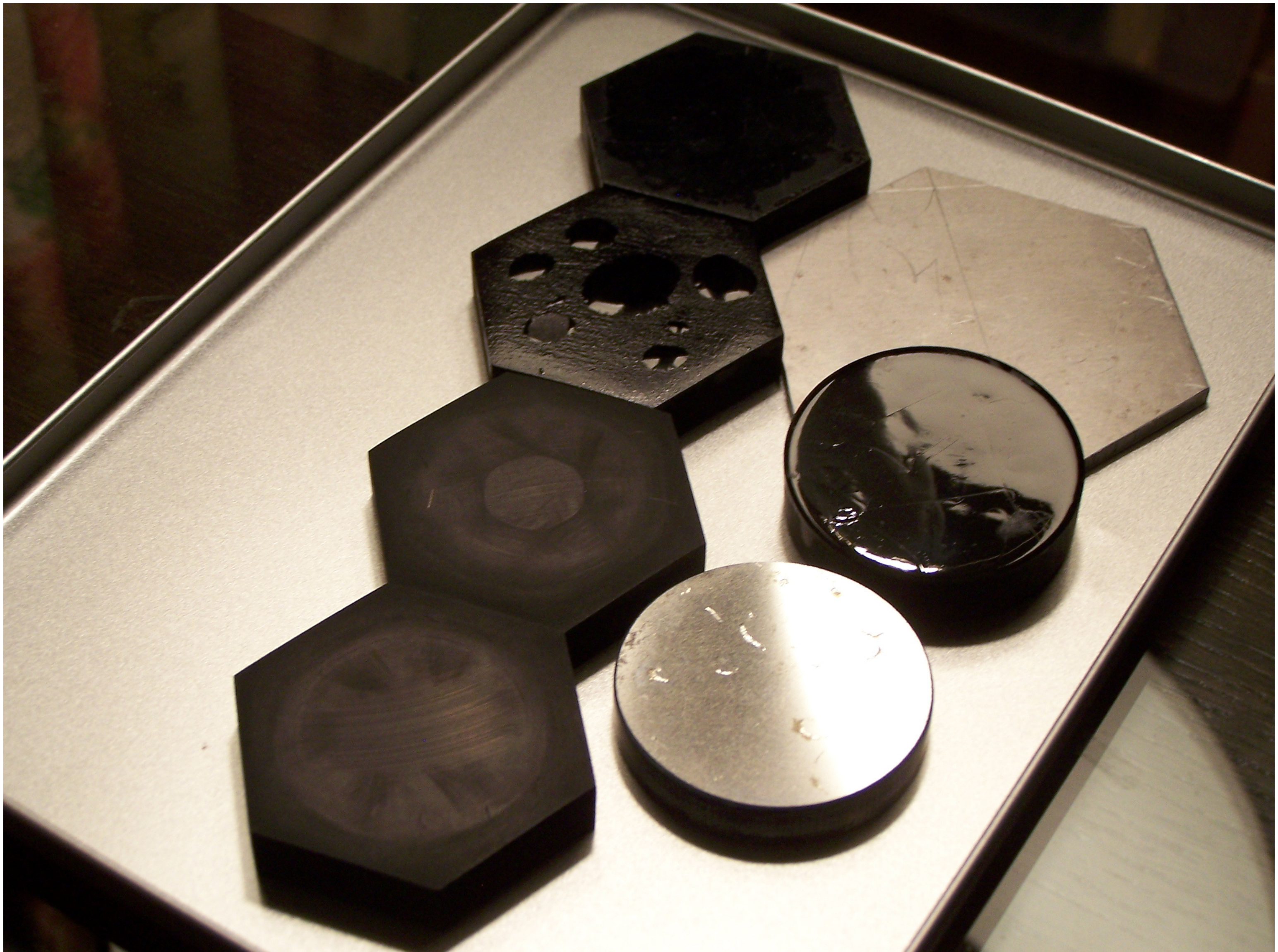

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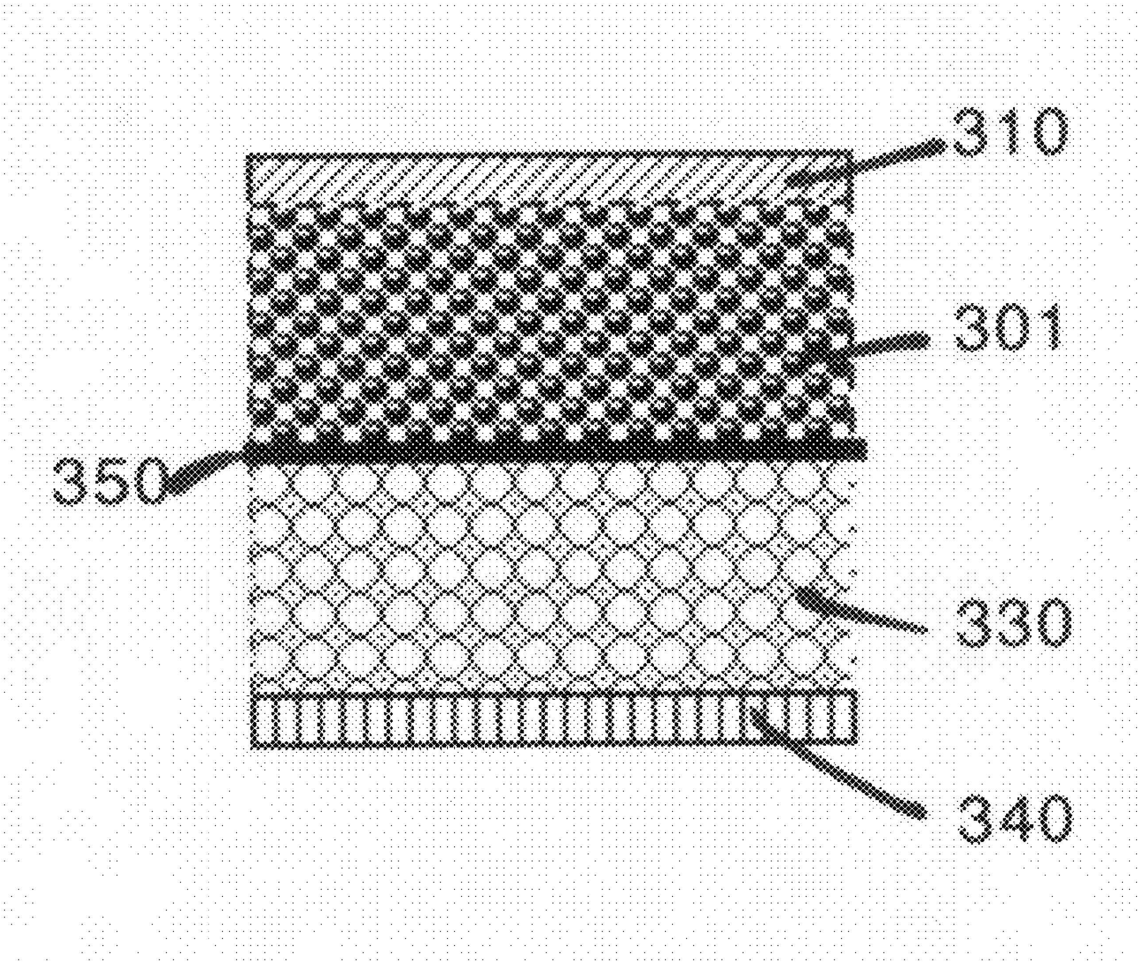

Critical Coating (& Interface) Dimensions

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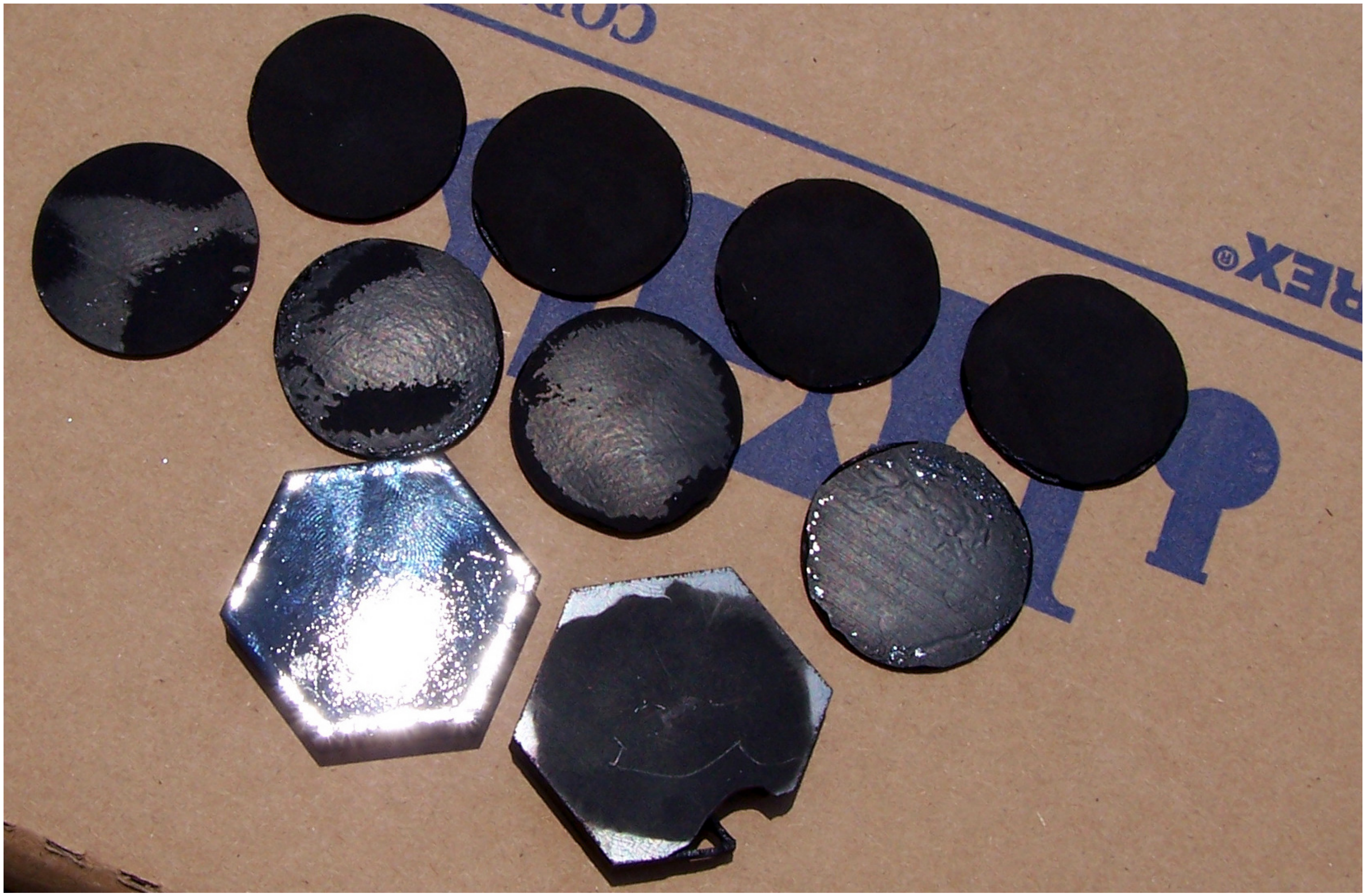

Scalability

Control Hexes, Replicated Wafers

(Months 1-4)

in 5 inch diameter Tubular Retort

(Months 5 & 6)

New 10 inch Cubic Retort

7 hexes, 6 orbiting a finished unit, with a combined flat / flat width exceeding 0,25 m

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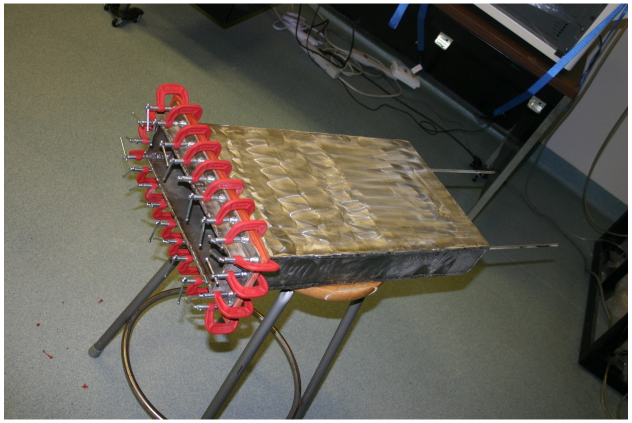
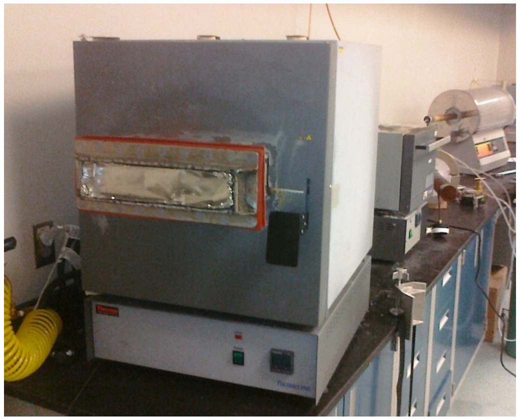
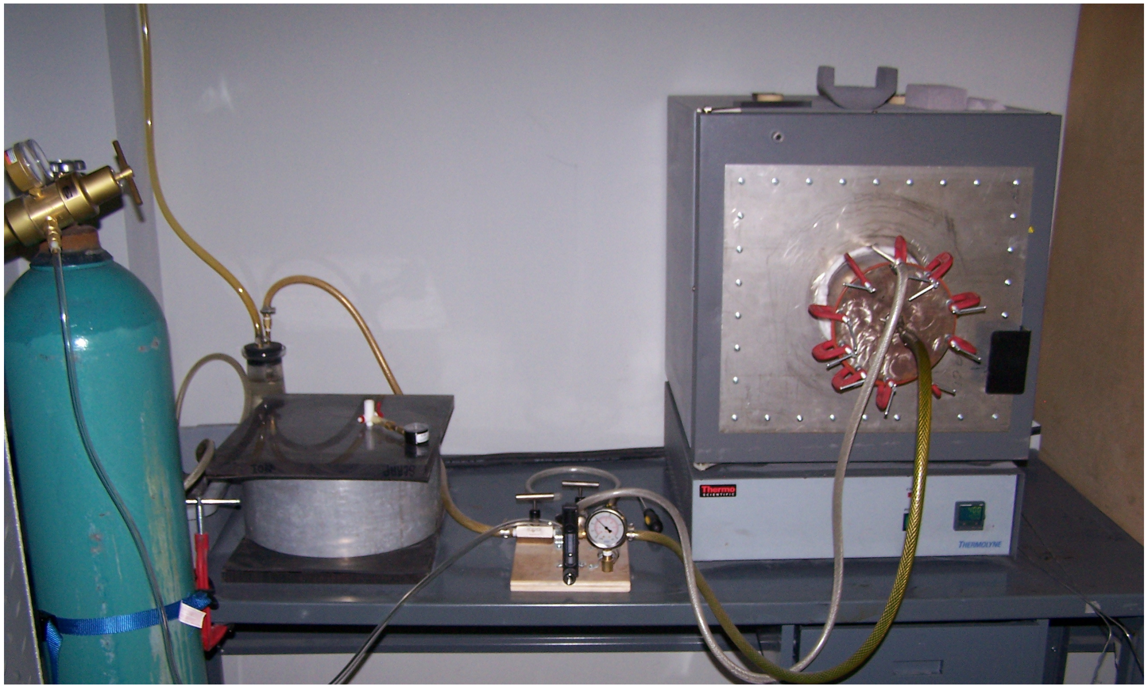
Your Ceramic From Atoms Up… Ceramicore© *Scalability*





Prior SBIR (Bulk Substrate)



Current SBIR (Coated Parts)

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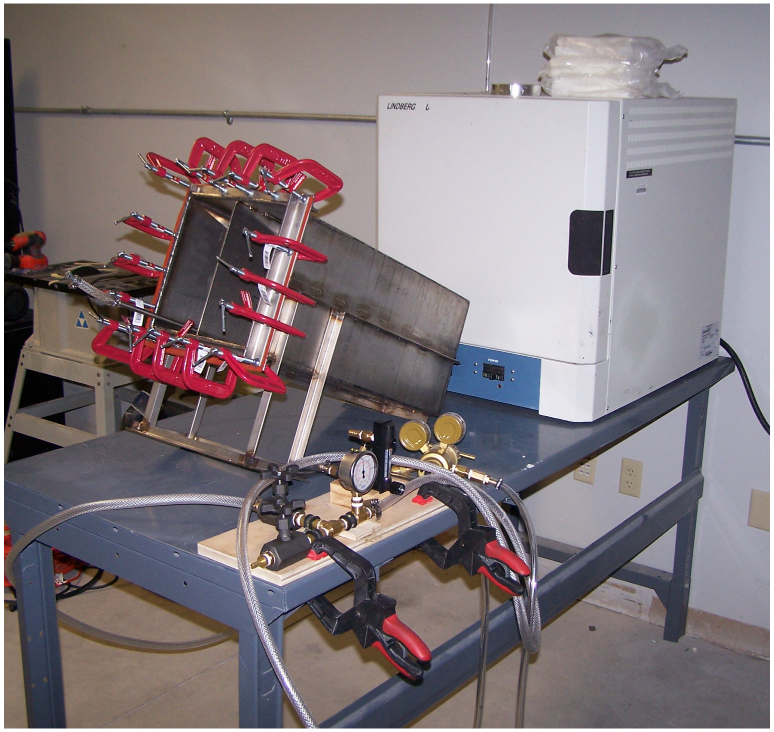

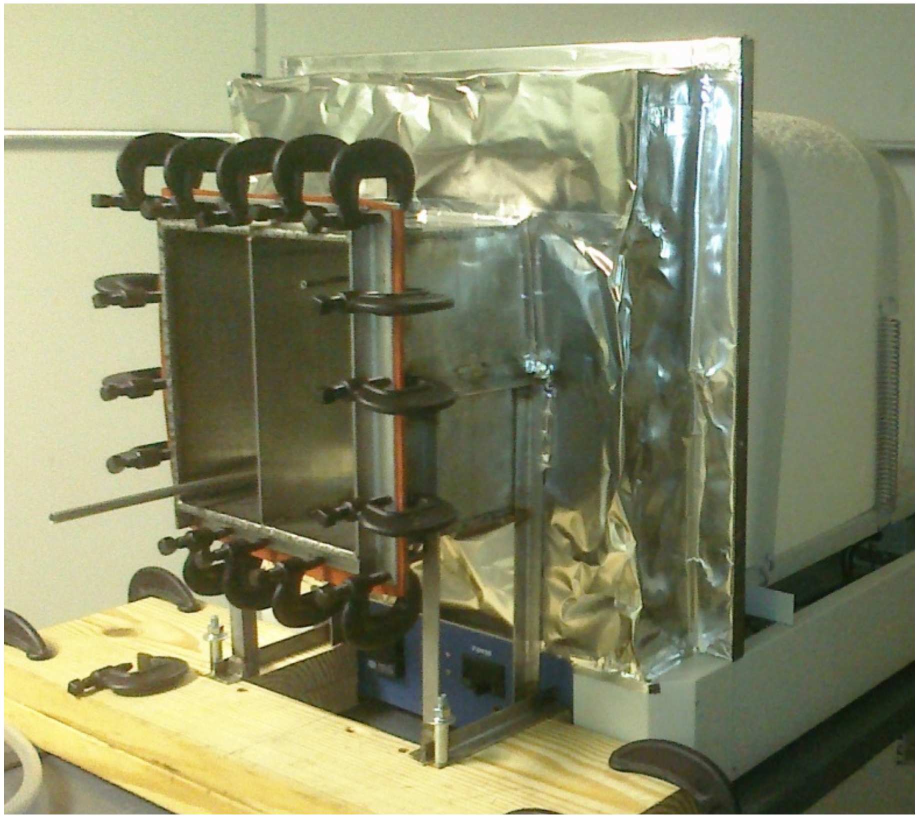

Current SBIR (Scaled Coated Parts)

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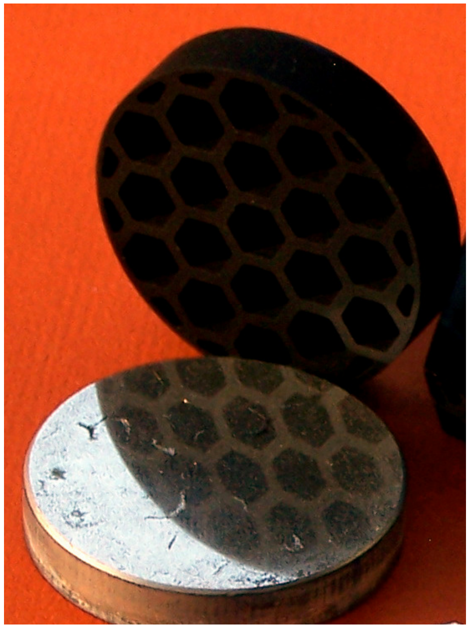
MEADE Instruments

Optical Figuring of Flats

UHTC Coating

Cost Driver to PYREX® on Terrestrial Product up to 0,5 m



A Polished and Metalized BULK Substrate Specimen

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Work In Process

Characterize Furnace and Retort 2

Create Final Replicate Tooling

Run Scaled up Replicates and Control Parts

Run ASTM Material Testing Samples

Figure and Metallize Flats at MEADE (1 plus 6)

Summary

Minimal Tooling

Low Volume, High Mix,

Low Total Cost To Part

Monolithic Structure

Isotropic Structural Properties

Homogeneous Material

Component Region Appropriate Density

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